

# METHOD OF ESTIMATION PARAMETER ADAPTABILITY ADJUSTMENT OF AN OPTICAL STORAGE DEVICE

## DESCRIPTION

### Background

[Para 1] The invention generally relates to a method for adjusting estimation parameters of an optical storage device, and more particularly, to a method of estimation parameter adaptability adjustment of an optical storage device.

[Para 2] Following the increase in calculation speed of computer systems and the progression of internet, the requirement for data storage of different computer users increases accordingly. Due to the compact size, impressive storage capacity, and economical cost of an optical storage medium such as a compact disc (CD) or a digital versatile disc (DVD), an optical storage device such as a CD drive, a CD burner, a DVD drive, or a DVD burner for accessing the optical storage medium has become a standard accessory of computer systems.

[Para 3] Regarding the above-mentioned requirement, new CD/DVD specifications of larger storage capacity and prolonged recording time are introduced with a linear velocity up to 1.1 m/sec. However, when the recording time is greatly increased, the linear velocity will significantly deviate from a typical value of 1.3 m/sec of original specifications known in the art. In the optical storage device according to the related art, the deviation in linear velocity seriously affects parameter settings related to the channel bit rate. Therefore, the optical storage device cannot simultaneously satisfy the original specifications of conventional optical storage media and the new specifications of new popular optical storage media. For example, if a setting value of

VCODAC setting is not accurate, a frequency of a clock signal generated by a voltage-controlled oscillator (VCO) of the optical storage device cannot approach to a current channel bit rate so that a phase-locked loop (PLL) within the optical storage device cannot instantly lock onto the current channel bit rate. Therefore, the PLL cannot effectively operate.

[Para 4] In the optical storage device according to the related art, the parameter settings related to the channel bit rate are usually implemented by setting specific parameters or according to real-time and simple calculation results. However, regarding the adaptability of the optical storage device with respect to the optical storage media, complex mathematical calculations for the parameter settings are required. Therefore, in operation processes of the optical storage device, there is not enough time for such complex mathematical calculations and not enough information to perform adaptability adjustment to enhance the performance of the optical storage device.

## Summary

[Para 5] It is therefore an objective of the claimed invention to provide a method of estimation parameter adaptability adjustment of an optical storage device to solve the above-mentioned problem.

[Para 6] The present invention provides a method of estimation parameter adaptability adjustment of an optical storage device. The method determines an estimation parameter according to a current data recording location of the optical storage device to estimate a channel bit rate. The method includes providing a two-dimensional estimation parameter table. The two-dimensional estimation parameter table includes a plurality of estimation parameters corresponding to linear velocities and data recording locations. The method further includes determining a linear velocity estimation value; and determining the estimation parameter according to the linear velocity

estimation value, the current data recording location, and the two-dimensional estimation parameter table to estimate the channel bit rate.

[Para 7] An advantage of the present invention is that the two-dimensional estimation parameter table is designed according to the plurality of linear velocities of data recording and the data recording locations so that the estimation parameters of the two-dimensional estimation parameter table comply with the accuracy needed for different optical storage media being read at different linear velocities of data recording by the optical storage device. As a result, a frequency of a clock signal generated by a voltage-controlled oscillator (VCO) of the optical storage device may approach to a current channel bit rate so that a phase-locked loop (PLL) within the optical storage device can instantly lock onto the current channel bit rate to release the full potential of the PLL. On the other hand, after a seeking operation, the time that an IC of the optical storage device locks on the channel bit rate is reduced.

[Para 8] Another advantage of the present invention is that the two-dimensional estimation parameter table is designed according to the plurality of linear velocities of data recording and the data recording locations so that the estimation parameters of the two-dimensional estimation parameter table can compensate for the accuracy needed for some optical storage media having comparatively larger linear velocity deviations of data recording.

[Para 9] Another advantage of the present invention is that the present invention creates in advance the estimation parameter table having an adaptability adjustment function using the plurality of estimation parameters derived from complex mathematical calculations corresponding to the adaptability of the optical storage device with respect to the optical storage media. Therefore, when the optical storage device is in operation, parameter settings related to the channel bit rate is instantly obtained along with enough

information to perform adaptability adjustment to enhance the performance of the optical storage device.

[Para 10] These and other objectives of the present invention will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred embodiment that is illustrated in the various figures and drawings.

#### Brief Description of Drawings

[Para 11] Fig.1 is a diagram of a model used for a method of estimation parameter adjustment of an optical storage device according to one embodiment of the present invention.

[Para 12] Fig.2 is a flowchart of a method of estimation parameter adaptability adjustment of an optical storage device according to one embodiment of the present invention.

[Para 13] Fig.3 is a diagram of a model used for the method shown in Fig.2.

[Para 14] Fig.4 is an operational diagram of the interpolation operation shown in Fig.3.

[Para 15] Fig.5 is a diagram of a model used for a method of estimation parameter adaptability adjustment of an optical storage device according to another embodiment of the present invention.

#### Detailed Description

[Para 16] An optical storage medium known in the art includes a spiral track for data recording. According to the spiral track formula derived from fundamental calculus theorems, the relationship between the data recording

location L of the optical storage medium and the radius R of the optical storage medium is defined as

$$R = \sqrt{r_1^2 + \frac{p \times L}{\pi}}$$

[Para 17] wherein  $r_1$  is the radius of the inner track starting point, where L is zero, p is the track pitch, which is the radial distance between two consecutive tracks, and  $\pi$  is the ratio of the circumference of a circle to its diameter.

[Para 18] Using a DVD as an example, the data recording locations are defined in units of sectors and each sector has a track length of 5.1584 mm. For the T<sup>th</sup> sector in the DVD, the data recording location L is 5.1584T, and the corresponding radius R is

$$R = \sqrt{r_1^2 + \frac{5.1584 \times p \times T}{\pi}}$$

[Para 19] wherein the radius  $r_1$  of the inner track starting point of the DVD is 24 mm, and the track pitch p is 0.74  $\mu$ m.

[Para 20] Using a CD as an example, the data recording locations are defined in units of seconds and the track length for each second ranges from 1.2 m to 1.4 m (i.e. the linear velocity ranges from 1.2 m/sec to 1.4 m/sec). The data recording location L for the T<sup>th</sup> second ranges from 1.2T to 1.4T and the corresponding radius R is

$$R = \sqrt{r_1^2 + \frac{1.2 \times p \times T}{\pi}} \sim \sqrt{r_1^2 + \frac{1.4 \times p \times T}{\pi}}$$

[Para 21] wherein the radius  $r_1$  of the inner track starting point of the CD is 25 mm, and the track pitch p is 1.6  $\mu$ m.

**[Para 22]** The relationship among the linear velocity  $V$ , radius  $R$ , rotational frequency  $f$ , whose unit is "1/sec" (i.e. revolutions per second), and angular velocity  $\omega$  on the spiral track of the aforementioned optical storage medium is defined by

$$V = R \times \omega = 2 \times \pi \times R \times f$$

**[Para 23]** Therefore, the channel bit rate  $v$  of an optical storage device when accessing the optical storage medium is

$$v = \frac{V}{\varepsilon} = \frac{R \times \omega}{\varepsilon} = \frac{2 \times \pi \times R \times f}{\varepsilon}$$

**[Para 24]** wherein  $\varepsilon$  is the length of a bit in the optical storage medium, and the rotational frequency  $f$  of the optical storage device is determined according to a frequency generator counting value, the FGCNT value, explained as follows. The optical storage device includes a spindle motor for driving and rotating the optical storage medium. When the spindle motor rotates, the optical storage device detects the rotational frequency of the spindle motor using a hall sensor and correspondingly generates an FG signal representing the current rotational frequency. The digital signal processor (DSP) of the optical storage device receives the FG signal and measures the FG signal using a higher frequency clock signal with a frequency  $f_{cnt}$  to derive the FGCNT value, the number of periods that the higher frequency clock signal oscillates within one period of the spindle motor. Using the FGCNT value to represent the rotational frequency  $f$  is easier for the DSP to calculate, wherein the relationship among the rotational frequency  $f$ , the frequency  $f_{cnt}$  of the higher frequency clock signal, and the FGCNT value is

$$f = \frac{f_{cnt}}{FGCNT}$$

**[Para 25]** An rearrangement of the above two equations is derived as follows

$$v = \frac{V}{\varepsilon} = \frac{R \times \omega}{\varepsilon} = \frac{2 \times \pi \times R \times f}{\varepsilon} = \frac{2 \times \pi \times R \times f_{cnt}}{\varepsilon \times FGCNT} = \frac{K_w}{FGCNT}$$

[Para 26] wherein the estimation parameter Kv of the channel bit rate  $\nu$  is defined as follows

$$K_v = \frac{2 \times \pi \times R \times f_{\text{cnt}}}{\varepsilon} = \frac{2 \times \pi \times \sqrt{r_1^2 + \frac{p \times L}{\pi}} \times f_{\text{cnt}}}{\varepsilon}$$

[Para 27] Therefore, for each data recording location L, the estimation parameter Kv can be derived from the above calculation with the parameters for the CD and the DVD provided in the two aforementioned examples.

[Para 28] The initial set up of the optical storage device is to first create a one-dimensional estimation parameter table (ex. the table 102 in Fig.1) including a plurality of estimation parameters Kv corresponding to a plurality of data recording location L, wherein the plurality of estimation parameters Kv are calculated using the equations introduced above. The one-dimensional estimation parameter table is stored in a firmware of the optical storage device in advance. When the firmware is executed, an estimation parameter Kv out of the plurality of estimation parameters of the one-dimensional estimation parameter table is rapidly determined according to the data recording location L. The determined estimation parameter Kv is divided by the FGCNT value to rapidly estimate the channel bit rate  $\nu$ . Through instant estimation of the channel bit rate  $\nu$ , the optical storage device can complete parameter settings corresponding to the data recording location L in advance when performing data seek of the optical storage medium so that the performance of the optical storage device is enhanced. For example, the VCODAC setting of a voltage-controlled oscillator (VCO) of a phase-locked loop (PLL) of the optical storage device requires instant rapid estimation of the channel bit rate  $\nu$  and the input voltage of the VCO of the PLL will be set as a voltage corresponding to the estimated channel bit rate  $\nu$ . Therefore, when the estimation parameter table is precisely prepared to comply with the accuracy needed for the reading of the optical storage medium by the optical storage device so that the frequency of the clock signal generated by the VCO is very close to a current channel bit

rate, the PLL can rapidly lock onto the current channel bit rate to allow the best performance of the PLL.

[Para 29] Please refer to Fig.1 illustrating the first embodiment. Fig.1 is a diagram of a model used for a method of estimation parameter adjustment of an optical storage device according to the first embodiment of the present invention. In this embodiment, the optical storage device for accessing an optical storage medium is a CD drive, and the optical storage medium is a CD. As previously described, the data recording location L of the CD is defined in units of seconds. The CD drive in Fig.1 is designed with the track length of the CD per second assumed to be 1.3m. That is, the linear velocity for data recording is 1.3m/sec. At the  $T^{\text{th}}$  second, which is the "address time" shown in Fig.1, the data recording location L is  $1.3T$ . Fig.1 illustrates the above-mentioned one-dimensional estimation parameter table 102 including the plurality of estimation parameters  $K_0, K_1, K_2, K_3, \dots, K_n$ , wherein the estimation parameters correspond to the address times. When the firmware of the optical storage device is executed, the estimation parameter  $K_j$  out of the plurality of estimation parameters  $K_0, K_1, K_2, K_3, \dots, K_n$  is rapidly determined to be the estimation parameter 110, which is labeled as  $K_{V1.3}$  in Fig.1, according to the data recording location L, which is the current address time 101 shown in Fig.1, and then the estimation parameter  $K_{V1.3}$  is available for frequency estimation 150. The subscript V1.3 of the estimation parameter  $K_{V1.3}$  denotes that the one-dimensional estimation parameter table is created with an assumption that the linear velocity of data recording of the optical storage medium accessed by the optical storage device is 1.3m/sec. The frequency estimation 150 shown in Fig.1 generates the FGCNT value according to the FG signal sent from the integrated circuit (IC) 170, which includes the aforementioned DSP and PLL, and then the estimation parameter 110 is divided by the FGCNT value to rapidly determine the channel bit rate  $\gamma$ .

[Para 30] As mentioned, the one-dimensional estimation parameter table of the optical storage device according to the first embodiment is designed with



the assumption that the linear velocity of data recording of the optical storage medium is constant. That is, the track length per second on the optical storage medium is constant. According to the CD specifications, the linear velocity of data recording ranges from 1.2m/sec to 1.4m/sec. Therefore, regarding a CD of the median linear velocity, 1.3m/sec, the optical storage device according to the first embodiment will work properly using the estimation parameter table.

[Para 31] Please refer to Fig.2 and 3 at the same time. Fig.2 is a flowchart of a method of estimation parameter adaptability adjustment of an optical storage device according to one embodiment of the present invention. Fig.3 is a diagram of a model used for the method shown in Fig.2. The optical storage device according to the second embodiment of the present invention has a two-dimensional estimation parameter table 302 including estimation parameters  $K(i, j)$  ( $i=1, 2, 3, 4; j=1, 2, 3, 4, \dots, n$ ) derived from the aforementioned equations during a design phase. In this embodiment, the optical storage device for accessing an optical storage medium is a CD drive, and the optical storage medium is a CD. The two-dimensional estimation parameter table 302 is stored in a firmware of the optical storage device in advance. The optical storage device according to the second embodiment is designed for an optical storage medium with inconstant linear velocity of data recording and for an optical storage medium with non-typical linear velocity that is far from the median linear velocity, 1.3m/sec. This optical storage device is even suitable a certain optical storage medium with larger capacity, longer recording time, and linear velocity of 1.1m/sec. The related steps of the method is executed by the firmware of the optical storage device (a CD drive in this embodiment) for determining an estimation parameter according to a current data recording location of an optical storage medium accessed by the optical storage device to estimate the channel bit rate. The method is described as follows:

[Para 32] Step 10: Provide the two-dimensional estimation parameter table 302, wherein the two-dimensional estimation parameter table 302 includes the plurality of estimation parameters  $K(i, j)$  ( $i=1, 2, 3, 4; j=1, 2, 3, 4, \dots, n$ ).

The estimation parameters  $K(i, j)$  correspond to the linear velocity  $V$  (such as  $V=1.1, 1.2, 1.3, 1.4$ ) corresponding to  $i=1, 2, 3, 4$  respectively. The estimation parameters  $K(i, j)$  further correspond to the data recording location, which is labeled as “address time” in Fig.3, respectively corresponding to  $j=1, 2, 3, 4, \dots, n$ .

**[Para 33] Step 20:** Provide an interpolation index to determine an estimation parameter  $K_v$  out of the plurality of estimation parameters  $K(i, j)$  using an interpolation operation 330 with respect to the interpolation index to estimate the channel bit rate as the frequency estimation 350 shown in Fig.3 performs, wherein the interpolation index corresponds to the linear velocity  $V$ .

**[Para 34] Step 30:** Determine a linear velocity estimation value  $V_{est}$  ( $V_{est} = 1.1 \sim 1.4$ ) for looking up along the linear velocity  $V$ , which is an axis illustrated with the two-dimensional estimation parameter table 302 in Fig.3, while determining a value of the interpolation index to determine the linear velocity estimation value  $V_{est}$  simultaneously.

**[Para 35] Step 40:** Determine an estimation parameter  $K_v$  out of the estimation parameters  $K(i, j)$  according to the linear velocity estimation value  $V_{est}$ , the data recording location, which is labeled as “current address time” 301 in Fig. 3, and the two-dimensional estimation parameter table 302 to estimate the channel bit rate. As shown in Fig.3, the estimation parameters  $K(1, j), K(2, j), K(3, j), K(4, j)$  corresponding to the current address time 301 respectively are selected from the two-dimensional estimation parameter table 302 and are considered to be the estimation parameters  $K_{v1.1}, K_{v1.2}, K_{v1.3}, K_{v1.4}$  respectively so that the estimation parameter  $K_v$  is derived from the interpolation operation 330.

**[Para 36] Step 50:** Compare the estimated channel bit rate, which is labeled as “Estimated frequency 392” in Fig.3, with a current channel bit rate, which is labeled as “Locked frequency 394”, to reduce a difference between the estimated channel bit rate and the current channel bit rate by repeating step 30. As shown in Fig.3, according to the comparison output, “up/down 396” of the comparing operation 390, the interpolation index is increased or decreased accordingly to reduce the difference between the estimated channel bit rate 392 and the current channel bit rate 394.

[Para 37] As mentioned above, the data recording location L for data recording on the CD is defined in units of seconds. The optical storage device shown in Fig.3 is designed with an assumption that the track length per second of the CD ranges from 1.1m to 1.4m. That is, the linear velocity of data recording ranges from 1.1m/sec to 1.4m/sec. Therefore for the T<sup>th</sup> second, the data recording location L, which is labeled as the “address time” in Fig.3, ranges from 1.1T to 1.4T.

[Para 38] As shown in Fig.3, the two-dimensional estimation parameter table 302 provided in step 10 includes a plurality of one-dimensional estimation parameter tables 3021, 3022, 3023, 3024. When the firmware of the optical storage device is executed, the estimation parameters K(1, j), K(2, j), K(3, j), K(4, j) out of the plurality of one-dimensional estimation parameter tables 3021, 3022, 3023, 3024 respectively are rapidly selected from the two-dimensional estimation parameter table 302. The estimation parameters K(1, j), K(2, j), K(3, j), K(4, j) are considered to be the estimation parameters 311, 312, 313, 314 (i.e. Kv1.1, Kv1.2, Kv1.3, Kv1.4) provided for the interpolation operation 330 generating the estimation parameter Kv for the frequency estimation 350. Similarly, the subscript V1.3 of the estimation parameter Kv1.3 denotes that the one-dimensional estimation parameter table 3023 is created with an assumption that the linear velocity of data recording of the optical storage medium accessed by the optical storage device is 1.3m/sec. Therefore, the subscripts V1.1, V1.2, V1.3, and V1.4 correspond to the linear velocity of 1.1m/sec, 1.2m/sec, 1.3m/sec, and 1.4m/sec, respectively.

[Para 39] In step 20, hexadecimal values 0xff, 0xaa, 0x55, and 0x00 (“0x” is a hexadecimal notation known in the art) of the interpolation index respectively correspond to the linear velocity of 1.1m/sec, 1.2m/sec, 1.3m/sec, and 1.4m/sec. In this embodiment, Step 30 can be repeated. When first executing step 30, the linear velocity estimation value V<sub>est</sub> can be initially determined to be 1.3m/sec while determining a value 0x55 of the interpolation index.

Regarding the loop of the interpolation operation 330, the frequency estimation 350, and the comparing operation 390, as the linear velocity estimation value  $V_{est}$  initially determined in step 30 is an initial status of the loop, repeated operations of steps 30, 40, and 50 will make the estimated channel bit rate 392 close to the current channel bit rate 394.

[Para 40] Please refer to Fig.4 illustrating an operational diagram of the interpolation operation 330 shown in Fig.3. The horizontal axis denotes the interpolation index, which is labeled as “index” in Fig.4, and the vertical axis denotes the estimation parameter  $K_v$  shown in Fig.3. The interpolation function 332 shown in Fig.4 illustrates that the estimation parameters  $K_{v1.1}$ ,  $K_{v1.2}$ ,  $K_{v1.3}$ , and  $K_{v1.4}$  respectively correspond to the hexadecimal values 0xff, 0xaa, 0x55, and 0x00 of the interpolation index. In this embodiment, the interpolation index ranges from the hexadecimal value 0x00 to the hexadecimal value 0xff, wherein substituting a value of the interpolation index into the interpolation function 332 generates the corresponding estimation parameter  $K_v$ . During the repeated operations of steps 30, 40, and 50, the firmware receives the FGCNT value derived from the FG signal received from the IC 370, which includes the aforementioned DSP and PLL. The estimation parameter  $K_v$  is then divided by the FGCNT value to generate the estimated channel bit rate 392. The comparing operation 390 compares the estimated channel bit rate 392 and the current channel bit rate 394 to determine if the interpolation index should be increased or decreased according to the comparison output, up/down 396, of the comparing operation 390. If the firmware finds that the estimated channel bit rate 392 is less than the current channel bit rate 394, the interpolation index is increased according to the comparison output 396 to decrease the linear velocity estimation value  $V_{est}$ . If the firmware finds that the estimated channel bit rate 392 is more than the current channel bit rate 394, the interpolation index is decreased according to the comparison output 396 to increase the linear velocity estimation value  $V_{est}$ .

[Para 41] According to the deduction of the previous formulas, the rotational frequency  $f$  is dependent on the FGCNT value. The method of the present invention further includes determining the current rotational frequency  $f$  according to the FGCNT value. It is a design choice of the implementation of the present invention. In another embodiment of the present invention, the firmware may utilize a replacement circuit to derive the rotational frequency  $f$  represented by the FG signal, wherein the estimation parameters are obtained by the mathematical calculations of the replacement circuit. Therefore the method of the present invention further includes estimating the channel bit rate  $v$  according to the current rotational frequency  $f$  and the estimation parameter  $K_v$  determined in step 40.

[Para 42] In step 50, the comparing operation 390 compares the estimated channel bit rate 392 with the current channel bit rate 394 to reduce the difference between the estimated channel bit rate 392 and the current channel bit rate 394 by repeating step 30. This is a design choice of the implementation of the present invention. The time required for the PLL to lock indicates the accuracy of the estimated channel bit rate. In another embodiment of the present invention, the linear velocity estimation value  $V_{est}$  is re-determined according to frequency locking time, the time required for the PLL to lock. The method of the present invention further includes monitoring the frequency locking time to reduce the difference between the estimated channel bit rate and the current channel bit rate by repeating step 30.

[Para 43] Within the PLL, there is a current pump 374, which is shown in Fig.5, for controlling the input voltage of the VCO. By controlling the charge and discharge 375 of the current pump 374, the PLL is capable of controlling the input voltage of the VCO to change the current channel bit rate 394. Therefore, a checking circuit such as an integration circuit (not shown in Fig.5) is used to check charging and discharging 375 of the current pump 374 or check a logic signal 373 of the current pump 374 to detect the difference

between the estimated channel bit rate 392 and the current channel bit rate 394. If the estimated channel bit rate 392 is less than the current channel bit rate 394, the PLL controls the current pump 374 to charge to increase the channel bit rate. If the estimated channel bit rate 392 is more than the current channel bit rate 394, the PLL controls the current pump 374 to discharge to decrease the channel bit rate. Therefore, according to this embodiment, the present invention method may detect the difference between the estimated channel bit rate 392 and the current channel bit rate 394 and re-determine the linear velocity estimation value  $V_{est}$  so that a number of times of charging and discharging 375 of the current pump 374 is reduced. It is a design choice of the implementation of the present invention and is illustrated with Fig.5. Therefore, the method further includes checking charging and discharging 375 of the current pump 374 of the PLL of the optical storage device to reduce the number of times of charging and discharging 375 of the current pump 374 by adjusting a value of the interpolation index or adjusting the linear velocity estimation value  $V_{est}$ . The method further includes checking a logic signal 373 of a current pump 374 of the PLL of the optical storage device to reduce the number of times of charging and discharging 375 of the current pump 374 by adjusting a value of the interpolation index or adjusting the linear velocity estimation value  $V_{est}$ .

[Para 44] An advantage of the present invention is that the two-dimensional estimation parameter table is designed according to the plurality of linear velocities of data recording and the data recording locations so that the estimation parameters of the two-dimensional estimation parameter table comply with the accuracy needed for different optical storage media being read at different linear velocities of data recording by the optical storage device. As a result, the frequency of the clock signal generated by the VCO of the optical storage device may approach to the current channel bit rate so that the PLL within the optical storage device can instantly lock onto the current channel bit rate to release the full potential of the PLL. On the other hand, after

a seeking operation, the time that an IC of the optical storage device locks on the channel bit rate is reduced.

[Para 45] Another advantage of the present invention is that the two-dimensional estimation parameter table is designed according to the plurality of linear velocities of data recording and the data recording locations so that the estimation parameters of the two-dimensional estimation parameter table can compensate for the accuracy needed for some optical storage media having comparatively larger linear velocity deviations of data recording.

[Para 46] Another advantage of the present invention is that the present invention creates in advance the estimation parameter table having an adaptability adjustment function using the plurality of estimation parameters derived from complex mathematical calculations corresponding to the adaptability of the optical storage device with respect to the optical storage media. Therefore, when the optical storage device is in operation, parameter settings related to the channel bit rate is instantly obtained along with enough information to perform adaptability adjustment to enhance the performance of the optical storage device.

[Para 47] Those skilled in the art will readily observe that numerous modifications and alterations of the device may be made while retaining the teachings of the invention. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.